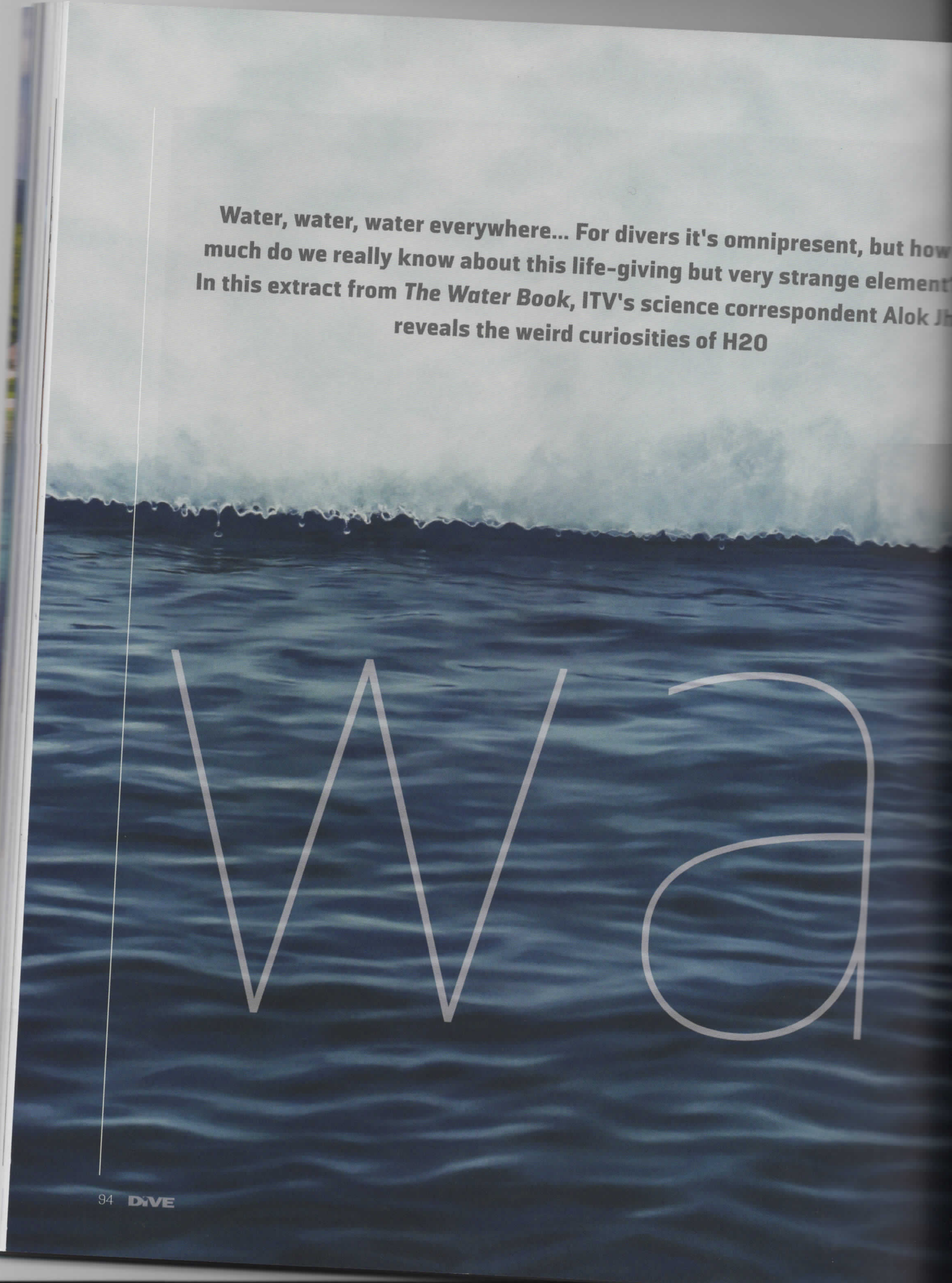
Water, water, water everywhere... For divers it's omnipresent, but how much do we really know about this life-giving but very strange element? In this extract from *The Water Book*, ITV's science correspondent Alok Jh reveals the weird curiosities of H20



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Lemaire Channel Antarctica by
Zaria Forman

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crystal can start to get an initial purchase and start to grow. These starting points could be bubbles, for example, or rough areas on the surface of the container. If there are none of these around and the temperature keeps dropping, the water can become supercooled and remain liquid well below its expected freezing point. Supercooled water is not entirely stable though, and will instantly freeze if nucleation is somehow started within it. (It works the other way too – superheated water can remain liquid well past the usual boiling point of 100°C on the surface of the Earth).

Since hot water has fewer impurities and potential nucleation points than colder water, it can become supercooled more easily. As colder water freezes, it forms a layer of ice at the top that insulates the rest of the volume underneath from the cold air outside. That slows down the rate at which the rest of the liquid can freeze. In the case of supercooled water, however, there is no such ice and no insulation. The liquid therefore freezes more rapidly once nucleation does somehow get started.

STICKY SITUATION

Many of the anomalous behaviours we have encountered can be traced back to an intriguing ability that water molecules have to temporarily attach themselves to things, particularly each other. This 'stickiness' not only explains why ice floats and water behaves in odd ways with regards temperature, it is the key to understanding why water became the medium of life.

At the macroscopic level, water's stickiness gives it a strong surface tension, a property that insects use to skate across the surface of ponds. That same stickiness means that water molecules easily pull each other up through empty pores and vessels by capillary action – the ability of

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Maldives by Zaria Forman

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a liquid to flow in very narrow channels without the action of (and often in opposition to) an external force, such as gravity. This is how water moves up so easily through a tissue paper or a sponge; it is also how plants suck water up from deep below the surface of the Earth in order to nourish the leaves and branches growing in the sunshine.

Water's stickiness is profoundly useful to us because it makes liquid water so incompressible. Squeezing orange juice out of a carton, for example, or pumping water around plumbing in a house or through a hose can only work because applying a pressure at one side of a volume of liquid water moves it so easily. If water was more easily compressed (or, rather, if it was as easily compressed as other liquids) moving it around in the quantities we need for modern life would be expensive and difficult. (A liquid being incompressible might not sound so abnormal, by the way, but water takes it to a different and weird level – even at a mile deep, the ocean's water is only squashed in volume by only about one per cent.)

All of this stickiness comes about because, at the molecular level, water molecules are attracted to each other to an extent we do not see with other liquids. Each water molecule is shaped like a shallow V, with the large oxygen atom at the apex and the smaller hydrogen atoms at the ends of the arms. The atoms within an individual molecule are bound together by covalent bonds, in which the atoms share their outer shells of electrons. Overall, each H2O molecule is electrically neutral but zoom in and you find that the two hydrogen atoms are fractionally positive, compared to the fractionally negative oxygen atom at the centre of the V – the molecule has positive and negative electrical sections, like north and south poles on a magnet. And like magnets, this polarity in water leads to attraction between different molecules as the hydrogen atoms of one water molecule are weakly drawn towards the oxygen atom of another molecule. This 'hydrogen bond' between water molecules has profound consequences for how water behaves at the temperatures and pressures we are familiar with on Earth and it is critical for the functions of life.

Minuscule, ephemeral, ever-shifting molecule-to-molecule attractions give liquid water a little more cohesiveness than is found in other liquids, just enough so that liquid water needs more energy, overall, in order to boil up into a gas. That means we end up with a liquid at the temperatures and pressures on Earth where we might otherwise have expected a gas. This hydrogen-bonded network also explains why ice is less dense than cold liquid water. In other liquids, where hydrogen bonds do not form networks, the molecules can end up drifting extremely close to each other, meaning the liquid ends up becoming relatively dense. In liquid water, there are two opposing forces at play. For a start, the hydrogen bonds want to force the water molecules into pyramid-shaped networks that end up leaving lots of empty space between the molecules (they create an 'open' structure). Working against that imposition of order is the inevitable chaotic maelstrom of a liquid. Because the water molecules all tumble around through the liquid, the perfect pyramids of the hydrogen-bonded networks do not always come together. In many places, the water molecules will drift closer than they should if the hydrogen bonds were in total control. On average, those small imperfections in the network of pyramids mean that liquid water is not as open as it should be – there is less space between molecules, in other words, than you

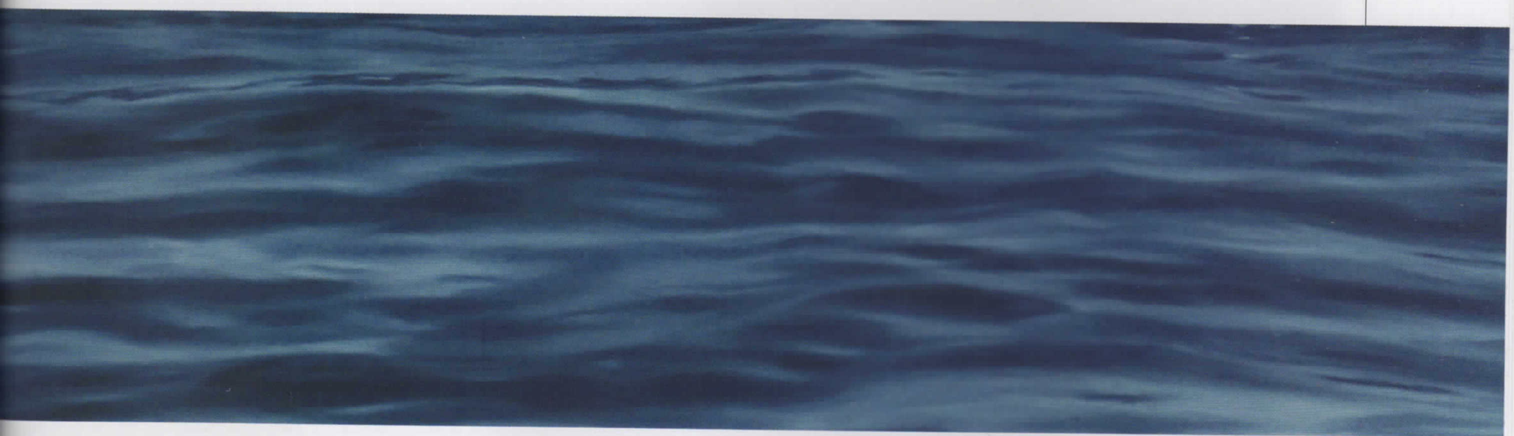
> “This curious anomaly of water has allowed complex life to survive and evolve despite the Earth's successive ice ages”

might otherwise expect if the pyramid structures were always perfectly formed.

When water is frozen into ice, however, those pyramid structures are forced to form perfectly. The solid network of water molecules in the crystal is therefore forced into its more open, and less dense, state. Hence ice is less dense than water, and it floats on the surface of the liquid.

SOLVENT BUSINESS

The polarity of the water molecule has another use fundamental to our life and that of our planet. The fractional difference in electrical charge across the V-shaped molecule not only makes water molecules stick to each other, it makes water the closest thing we have to a universal solvent, able to tear apart and nudge compounds that have any electrically-charged components.



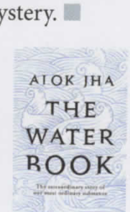
Sodium chloride (common salt), for example, dissolves in water because the polar water molecules tear the salt crystal apart. Liquid water is such a good solvent, in fact, that it is almost impossible to find naturally occurring pure samples and even producing it in the rarefied environment of the laboratory is difficult. Almost every known chemical compound will dissolve in water to a small extent. Related to this, because it will interact with everything over long periods of time, water is also one of the most reactive and corrosive chemicals we know.

This ability to react and dissolve also lies at the heart of water's ability to conduct electricity so well. We all know that it is dangerous to keep electrical wires wet and that you should never go near electrical sockets with wet hands. Pure water, though, is actually a very good insulator because, even though the hydrogen and oxygen atoms are fractionally charged, they cannot move independently of one another in order to set up a current within the liquid. Pure water, though, is hard to find and, as we know in the real world, the liquid will dissolve anything it can find.

Perhaps it is too simplistic, too reductionist, to say that life on Earth is a consequence of the chemical properties of water. But most of our biological functions (and indeed the movement and presence of water that made our environment so hospitable) can often be brought back to the way water molecules attract and dance around each other.

Think of a liquid and it will most likely be water. Even if you actively think of something else – blood, beer, apple juice – you're thinking of water with a small amount of other things dissolved or suspended within it. There are other pure liquids that appear in everyday life, such as petroleum or cooking oil, but not many and we hardly think or interact with these liquids to the extent we do with water. Water is so common and so familiar that it is mundane: every day we drink it, touch it, wash with it, wet things, dry things, we boil it, freeze it and even immerse ourselves within it by swimming or diving in it.

The anomalies outlined here are evident to us only because we can, with measurement and objectivity, stand outside our experience to watch it in action and compare it to the other materials we know about. The more we examine water, the stranger it gets, the more questions appear in front of us. We study it because we are made from it and it is, perhaps, surprising that what we are made from is still such a mystery. ■



· *The Water Book* (£20, hardback) is on sale now from Headline Publishing